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**CANMET**

Canada Centre for Mineral and Energy Technology | Centre canadien de la technologie des minéraux et de l'énergie

# PRELIMINARY RESULTS OF ROCK JOINT TESTING ON URL CORE

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# 1. INTRODUCTION

The mechanical behaviour of a rock mass involves the combined effects of the intact rock material, as well as the joint systems. A good understanding of both systems is required before the appropriate constitutive models can be developed to represent an overall rock mass behaviour.

Well established techniques exist for determining the intact rock material properties. In the case of fractured rock, some of the existing techniques for the evaluation of rock joint models involve the use of the index parameters of the joint systems.

In view of the difficulties associated with the quantitative estimation of rock joint properties on the basis of existing techniques, a contract was issued to Terra Tek Inc. of Salt Lake City, Utah, to provide a mechanical and hydraulic model for characterizing rock joint systems. Additionally, the contractor was to provide a methodology for field tests, and for collecting the necessary rock joint parameters, required as input data for the joint model.

It is expected that the rock joint model developed will eventually provide a means of estimating changes in rock joint conductivity under variable stress and temperature conditions. The joint model would also permit the development of a rock classification system for the research area rock bodies within the Canadian Nuclear Fuel Waste Management Program (NFWMP). This classification would be based on the Norwegian Geotechnical Institutes "Q" Index System.

The rock joint contract was fully discharged in 1983. A model for evaluating coupled hydraulic conductivity of joints, as well as a methodology for collecting field data were provided (Barton and Bakhtar, 1983). The data collection methodology has since been applied to Lac du Bonnet area joint core samples. The objective of the study was to characterize the research area rock joints on the basis of the Barton-Bandis joint model (Barton and Bakhtar, 1983). This report outlines the steps taken to develop the test equipment, provides a summary of the rock joint data to date, and recommends, on the basis of the current analysis, the need for future study.

## 1.1 SPECIAL FEATURES OF THE BARTON-BANDIS ROCK JOINT CHARACTERIZATION MODEL

The Barton-Bandis Joint Characterization Model (Barton and Bakhtar, 1983) offers a means for estimating the peak shear strength of joints largely based on the following expression:

$$\tau = \sigma_n \tan (JRC \log_{10} (\frac{JCS}{\sigma_n}) + \phi_r) \quad (1)$$

where: $\tau$ = shear strength of the joint (MPa)

$\sigma_n$ = normal force acting across the joint surface (MPa)

JRC = joint roughness coefficient

JCS = joint wall compressive strength (MPa)

$\phi_r$ = residual friction angle

A major advantage of the model is that values of $\phi_r$, JCS, and JRC can be determined easily using simple index tests. For example, a Schmidt rebound hammer is utilized to obtain an estimate of the weathered joint wall compressive strength (JCS) and the host rock's unweathered intact strength. Similarly, the basic friction angle, $\phi_b$, can be determined for most rocks by performing tilt tests on flat unweathered rock surfaces (generally two intact core surfaces). Having determined $\phi_b$ and the related rebound values for the fracture under consideration, the residual friction angle, $\phi_r$, can be estimated using the relationship:

$$\phi_r = (\phi_b - 20) + \frac{r}{R} * 20 \quad (2)$$

where: $\phi_r$ = residual friction angle

$\phi_b$ = basic friction angle

r = Schmidt rebound value on weathered joint surface

R = Schmidt rebound value on unweathered surface

The value of JRC is calculated by performing self-weight shear tests, in the form of tilt tests, on the fracture surfaces . Equation 1 can be rearranged into the form:

$$JRC = \frac{\alpha_o - \phi_r}{\log_{10}\left(\frac{JCS}{\sigma_{no}}\right)} \qquad (3)$$

where: $\alpha_o$ = tilt angle when sliding occurs

$\sigma_{no}$ = effective normal stress acting across the joint when sliding occurs

JRC may be determined by first resolving the normal force acting on the fracture surface at the the moment of sliding (i.e., failure) and replacing the value in Eq 3.

The joint roughness coefficient may also be estimated by visually comparing the joint with standard profiles established by Barton and Choubey, 1978, as shown in Fig. 1.

CANMET has developed equipment to perform the tests described here and, to date, 166 joint samples from the URL site have been studied.

## 2. EQUIPMENT DEVELOPMENT

### 2.1 SCHMIDT HAMMER TEST BASE

Core testing using a Schmidt hammer requires that a suitably massive specimen holder be manufactured to secure the sample (2). A 33 kg clamping mechanism was developed at CANMET. This consists of a lower 50 mm x 155 mm x 305 mm steel support base and a 50 mm x 75 mm x 155 mm upper clamping block. A 48 mm diameter semicircle was machined in the clamping block to accommodate the anticipated URL core diameter. Additional lateral support was gained by machining a 150° vee into the base. Two 13 mm x 102 mm hex bolts ran through the clamping block and were threaded into the base (see Fig. 2).

The Schmidt hammer used in the program was initially tested against a commercially available calibrating anvil*. Having determined that the hammer was within the manufacturer's specifications, its suitability for index testing was studied. Three rock types of known average strength, namely; a diabase, a limestone, and a granite obtained from borehole URL5 were used for this purpose. Two methods were used to estimate rock strength

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*Available through PROCEQ SA, Zurich, Switzerland.

with a Schmidt hammer. All three rock types were tested using the outside circumference of the core samples for strength determinations. The granite was also tested on a 45° sawcut surface to simulate a typical fracture orientation.

The test results are summarized in Table 1. There is some indications scatter in the data. This occurred independent of the test method used. It is also evident from the results that the amount of torque applied to the securing hex bolts clearly influenced the estimated strength values. Also, the torque required to obtain the best approximation of rock strength varied with the rock type.

A torque of 35 Nm was chosen on the basis of the URL5 granitic samples calibration data. These samples were considered to be representative of the rock types to be studied at the Underground Research Laboratory (URL) test site. The selection of a torque value of 35 Nm represented a compromise between obtaining the best correlation with actual strength values and avoiding breakage which tended to occur in the longer samples at higher torques. An attempt was made to install a deformable membrane in the clamping mechanism to distribute the load better but this procedure resulted in "drummy" readings and proved unsuitable.

## 2.2 TILT TABLES

The tilt table used for small scale testing was originally designed for determining basic friction angles using three pieces of core. The assembly consisted of a heavy levelling base on which a specimen holder was secured at one end by a pivot. The tilt angle was adjusted with a finely threaded rod (13 mm x 20) which ran through an axle at the opposite end and was capable of testing angles up to approximately 45°. The angle at which sliding was initiated was measured using an Abney level fixed to the specimen holder. The sides of the holder could be adjusted with two wing nuts to accommodate different core diameters (see Fig. 3).

Basic friction angles of the URL core were measured using this equipment in a relatively unmodified condition. The only addition required was higher sides to constrain the lateral movement when only two core sampler were used for testing. These consisted of two sheets of teflon which minimized side friction during testing.

Performing tilt tests on fractured core, however, necessitated a number of additional modifications. Sliding angles of up to 80° are not uncommon and this, coupled with an unadvantageous joint orientation, required the table to be capable of being rotated through 90°. A second specimen holder was manufactured which was fixed to the adjusting wing nuts of the original table. The new holder was capable of being preset at angles ranging from 0° to 45°, in 5° increments. This allowed the user to set the table at an angle just below that anticipated to initiate sliding. The test could then be completed using the threaded rod. The preset angle is added to that indicated by the Abney level to determine the true tilt angle (see Fig. 4).

Jointed blocks and core which could not be accommodated by the smaller specimen holder were tested on a larger tilt table. This consisted of two 300 mm x 550 mm boards which were hinged at one end. As sliding was initiated, the upper board could be fixed in place using a threaded rod which ran along grooved tracks attached to the lower board. The failure angle was then measured by laying a Brunton compass directly on the fracture surface (see Fig. 5).

## 2.3 PROFILOMETERS

It is often not practical to conduct one or more of the index tests on the joint under consideration. One recourse, in this instance, is to obtain a joint profile and compare this with a set of standard profiles (Section 1.1).

Generally, large scale profiles are made by placing a straight edge along the fracture surface and measuring the x,y coordinates of the asperities. Although this is an accepted method of mapping, it is very time consuming. To overcome this difficulty, a large scale profilometer was developed at CANMET. This consisted of 550-1mm tynes packed side by side in a single plane. The tynes were held between two 600 mm aluminum U-channels reinforced with tubular stiffeners. One inside surface was lined with foam rubber and the other had two thin metal rods running along its length. This system provided enough friction to permit the tynes to slide easily given sufficient pressure and yet maintain the fracture profile until it could be traced.

A small scale profilometer was used for most of the fracture surfaces studied. A commercially available, 150 mm carpenter's contour gauge was used for this purpose and works in a manner analogous to that of the large scale profilometer (see Fig. 6).

## 3. DATA SUMMARY

Basic fraction angle testing conducted on the Lac du Bonnet granite yielded a mean value of 31° which agreed well with values published in the literature. (Barton and Choubey, 1978).

To date, 166 joint samples have been studied under this program. The specimens have originated from two sources. These are the URL site drillholes in the Lac du Bonnet batholith, and from boreholes located at the instrumentation ring stations in the URL shaft. Of these, sufficient information was obtained for 139 samples to be characterized according to the Barton-Bandis (1981) joint model (in Barton and Bakhtar, 1983).

Table 2 contains data for 62 samples which were suitable for all index tests required by the model. Also included in this table are relevant sample information such as: sample identification (borehole number and downhole depth), strike and dip angles, uniaxial compressive strength, joint wall compressive strength and the type of infilling materials contained in the joints. Additionally, the calculated joint roughness coefficient (JRC) values, and shear strength estimates are tabulated in Table 2. The shear strength estimates have been made for normal stresses ranging from 0.001 to 100 MPa on the basis of the Barton-Bandis (1981) joint model.

Table 3 contains similar information to that found in Table 2. However, these samples could not be subjected to tilt tests because of any one of several reasons, including insufficient joint length and poor orientation. It was necessary, therefore, to visually estimate the joint roughness coefficient (JRC) values used for the shear strength approximations. Seventy seven (77) samples were examined under this category.

The predominant infilling material was red hematite, or hematite staining. This appeared on 63% (105) of the 166 samples studied. The bulk of the remaining infilling materials (and the number of joints these appeared on) include: calcite (66), chlorite (46), clay (24) and biotite (22). Pyrite (6), sericite (6), goethite-limonite (3), quartz (3), and purplish hematite (1) were also present.

For those samples which were subjected to both tilt and Schmidt hammer testing, the calculated JRC varied between 2.99 and 8.86. The mean and standard deviation JRC values were 6.45 and 1.40,respectively . These should be compared with the mean and standard deviation values of 6.0 and 1.9 for

samples whose JRC were estimated visually. The JRC values for this group of samples ranged from 3.5 to 13.0.

For the sake of comparison, the estimated value of JRC for sample URL1-49.94 was deliberately varied by + /-1.0 to determine the effects of such variations on the predicted peak shear strength. The results are contained in Table 4.

## 4. OBSERVATIONS AND CONCLUSIONS

The mean JRC of 6.45, calculated for the results in Table 2, agrees well with the range of JRC values (6.7 to 9.5) that was backcalculated by Barton and Choubey (1978) for slightly weathered tectonic joints in granite. The slightly reduced value can probably be attributed to the presence of infilling materials in most of the joints. The calculated JRC values fell within a narrow band about the mean, as is indicated by the low standard deviation value (1.4). The narrow variation resulted in estimated shear strength values which were consistent from joint to joint.

The results in Table 4 indicate that varying an estimated JRC by plus or minus one unit (+/-1), seems to affect the predicted peak shear strength value at low normal stress levels (0.001 to 0.01 MPa range). As the normal stress is increased to 0.1 MPa and beyond, however, the effect becomes negligible.

Correlations between the calculated JRC and parameters such as the strike and dip orientation of the joints, and sample depth, were poor for the investigated sample population. Various authors have noted, however, that the shear strength of a joint is profoundly affected by the thickness, strength and fabric of the infilling materials (Barton and Bakhtar, 1983; Lama and Vufukuri, 1978; Lama, 1978; Tulinov and Molokov, 1971). As testing continues, attempts are being made to relate the types and layering of infilling materials to the apparent decrease in JRC and consequent decrease in shear strength. Unfortunately, the strength and thickness of the infilling materials were not determined as part of the current test series.

## 5. RECOMMENDATIONS

Future studies should include some method of determining the average infilling thickness and, if possible, its strength. A program is currently under way to verify the model's predictions by conducting direct shear tests on joint surfaces. This study will also include tests to determine scale effects on joint behaviour.

## 6. ACKNOWLEDGEMENTS

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Table 1 - Schmidt hammer calibration test results

| Rock type | Density ($kN/m^3$) | Average compressive strength (MPa) | Applied torque (Nm) | Mean rebound number* | Indicated compressive strength (MPa)** |
|---|---|---|---|---|---|
| Diabase | 28.97 | 306 | 40 | 57.8 | 304 |
| | | $\sigma$ = 29 | 43 | 58.4 | 315 |
| | | | 45 | 59.6 | 338 |
| Limestone | 22.64 | 61 | 29 | 40.4 | 65 |
| | | $\sigma$ = 12 | 30 | 42.2 | 71 |
| URL5 129.5 | 25.79 | 191 | 35 | 56.4 | 195 |
| | | $\sigma$ = 24 | 37 | 57.2 | 203 |
| | | | 40 | 58.8 | 221 |
| URL5 129.5*** | 25.79 | 191 | 35 | 54.2 | 174 |
| | | $\sigma$ = 24 | 37 | 55.4 | 185 |
| | | | 39 | 56.2 | 193 |

*represents the mean of the top 5 values of 10 measurements taken.

**calculated using the equation: compressive strength (MPa) = $\log_{10}$(0.00088* density ($kN/m^3$)* rebound no. + 1.01) after Miller (1965).

***measurements taken on 45° sawcut to the core axis.

Table 2 - Joint sample properties: Calculated joint roughness coefficient (JRC)

PEAK SHEAR STRENGTH ESTIMATION

| SAMPLE NUMBER | STRIKE | DIP | UNIAXIAL COMP. STRENGTH (MPa) | JOINT WALL COMP. STRENGTH (MPa) | JRC | NORMAL STRESS (MPa) | SHEAR STRENGTH (MPa) | INFILLING MATERIAL |
|---|---|---|---|---|---|---|---|---|
| 275-SM-W75 6.85 | 292. | 70. | 206. | 110. | 6.50 | | | CL,CA,GO |
| | | | | | | 0.001 | 0.002 | |
| | | | | | | 0.010 | 0.013 | |
| | | | | | | 0.100 | 0.102 | |
| | | | | | | 1.000 | 0.812 | |
| | | | | | | 10.000 | 6.388 | |
| | | | | | | 100.000 | 48.917 | |
| 275-SM-W83 2.35 | 200. | 81. | 168. | 97. | 8.86 | | | HE,CL,CA,PY |
| | | | | | | 0.001 | 0.003 | |
| | | | | | | 0.010 | 0.018 | |
| | | | | | | 0.100 | 0.131 | |
| | | | | | | 1.000 | 0.955 | |
| | | | | | | 10.000 | 6.958 | |
| | | | | | | 100.000 | 48.703 | |
| 228-SM-E75 2.318 | 106. | 89. | 181. | 129. | 7.15 | | | CA,HE,CY |
| | | | | | | 0.001 | 0.002 | |
| | | | | | | 0.010 | 0.015 | |
| | | | | | | 0.100 | 0.119 | |
| | | | | | | 1.000 | 0.923 | |
| | | | | | | 10.000 | 7.152 | |
| | | | | | | 100.000 | 54.129 | |
| 228-SM-E75 3.937 | 213. | 87. | 223. | 153. | 7.45 | | | CA,CY,HE |
| | | | | | | 0.001 | 0.002 | |
| | | | | | | 0.010 | 0.016 | |
| | | | | | | 0.100 | 0.125 | |
| | | | | | | 1.000 | 0.961 | |
| | | | | | | 10.000 | 7.372 | |
| | | | | | | 100.000 | 55.319 | |
| 228-SM-E75 4.552 | 212. | 87. | 201. | 124. | 5.83 | | | CY,CA,HE,CL |
| | | | | | | 0.001 | 0.002 | |
| | | | | | | 0.010 | 0.012 | |
| | | | | | | 0.100 | 0.099 | |
| | | | | | | 1.000 | 0.808 | |
| | | | | | | 10.000 | 6.518 | |
| | | | | | | 100.000 | 51.537 | |
| 228-SM-E75 5.422 | 217. | 88. | 182. | 106. | 5.44 | | | CA,HE,CY,CL |
| | | | | | | 0.001 | 0.001 | |
| | | | | | | 0.010 | 0.011 | |
| | | | | | | 0.100 | 0.092 | |
| | | | | | | 1.000 | 0.760 | |
| | | | | | | 10.000 | 6.201 | |
| | | | | | | 100.000 | 49.562 | |

## PEAK SHEAR STRENGTH ESTIMATION

| SAMPLE NUMBER | STRIKE | DIP | UNIAXIAL COMP. STRENGTH (MPa) | JOINT WALL COMP. STRENGTH (MPa) | JRC | NORMAL STRESS (MPa) | SHEAR STRENGTH (MPa) | INFILLING MATERIAL |
|---|---|---|---|---|---|---|---|---|
| 228-SM-E75 5.699 | 175. | 81. | 182. | 93. | 7.73 | | | CA,HE,CY |
| | | | | | | 0.001 | 0.002 | |
| | | | | | | 0.010 | 0.015 | |
| | | | | | | 0.100 | 0.112 | |
| | | | | | | 1.000 | 0.855 | |
| | | | | | | 10.000 | 6.440 | |
| | | | | | | 100.000 | 46.734 | |
| 228-SM-E83 3.185 | 146. | 83. | 160. | 125. | 8.75 | | | CA,GO |
| | | | | | | 0.001 | 0.003 | |
| | | | | | | 0.010 | 0.021 | |
| | | | | | | 0.100 | 0.144 | |
| | | | | | | 1.000 | 1.054 | |
| | | | | | | 10.000 | 7.748 | |
| | | | | | | 100.000 | 55.471 | |
| 228-SM-S75 4.505 | 195. | 84. | 219. | 176. | 6.32 | | | NO |
| | | | | | | 0.001 | 0.002 | |
| | | | | | | 0.010 | 0.015 | |
| | | | | | | 0.100 | 0.115 | |
| | | | | | | 1.000 | 0.925 | |
| | | | | | | 10.000 | 7.383 | |
| | | | | | | 100.000 | 58.000 | |
| 228-SM-S83 8.315 | 160. | 88. | 219. | 129. | 7.04 | | | NO |
| | | | | | | 0.001 | 0.002 | |
| | | | | | | 0.010 | 0.015 | |
| | | | | | | 0.100 | 0.113 | |
| | | | | | | 1.000 | 0.881 | |
| | | | | | | 10.000 | 6.829 | |
| | | | | | | 100.000 | 51.599 | |
| 105-SM-N75 4.35 | 30. | 82. | 211. | 135. | 6.56 | | | CA,HE,CY |
| | | | | | | 0.001 | 0.002 | |
| | | | | | | 0.010 | 0.014 | |
| | | | | | | 0.100 | 0.110 | |
| | | | | | | 1.000 | 0.871 | |
| | | | | | | 10.000 | 6.875 | |
| | | | | | | 100.000 | 53.058 | |
| 105-SM-N75 4.75 | 40. | 83. | 198. | 145. | 6.00 | | | CA,HE,CY |
| | | | | | | 0.001 | 0.002 | |
| | | | | | | 0.010 | 0.013 | |
| | | | | | | 0.100 | 0.107 | |
| | | | | | | 1.000 | 0.865 | |
| | | | | | | 10.000 | 6.964 | |
| | | | | | | 100.000 | 55.099 | |

## PEAK SHEAR STRENGTH ESTIMATION

| SAMPLE NUMBER | STRIKE | DIP | UNIAXIAL COMP. STRENGTH (MPa) | JOINT WALL COMP. STRENGTH (MPa) | JRC | NORMAL STRESS (MPa) | SHEAR STRENGTH (MPa) | INFILLING MATERIAL |
|---|---|---|---|---|---|---|---|---|
| 105-SM-N75 6.50 | 204. | 89. | 198. | 128. | 6.67 | | | CA,HE,CY |
| | | | | | | 0.001 | 0.002 | |
| | | | | | | 0.010 | 0.014 | |
| | | | | | | 0.100 | 0.110 | |
| | | | | | | 1.000 | 0.873 | |
| | | | | | | 10.000 | 6.860 | |
| | | | | | | 100.000 | 52.670 | |
| 105-SM-N75 7.42 | 25. | 86. | 213. | 96. | 5.91 | | | CA,HE,CY |
| | | | | | | 0.001 | 0.001 | |
| | | | | | | 0.010 | 0.011 | |
| | | | | | | 0.100 | 0.091 | |
| | | | | | | 1.000 | 0.738 | |
| | | | | | | 10.000 | 5.896 | |
| | | | | | | 100.000 | 45.815 | |
| 105-SM-N83 4.70 | 9. | 84. | 224. | 148. | 6.07 | | | CA,HE,CL |
| | | | | | | 0.001 | 0.002 | |
| | | | | | | 0.010 | 0.013 | |
| | | | | | | 0.100 | 0.106 | |
| | | | | | | 1.000 | 0.854 | |
| | | | | | | 10.000 | 6.850 | |
| | | | | | | 100.000 | 53.933 | |
| 105-SM-N83 7.10 | 8. | 89. | 239. | 180. | 6.97 | | | CA,HE,CL |
| | | | | | | 0.001 | 0.002 | |
| | | | | | | 0.010 | 0.016 | |
| | | | | | | 0.100 | 0.123 | |
| | | | | | | 1.000 | 0.962 | |
| | | | | | | 10.000 | 7.514 | |
| | | | | | | 100.000 | 57.622 | |
| 105-SM-N83 7.90 | 188. | 89. | 239. | 126. | 7.18 | | | CA,HE,CL |
| | | | | | | 0.001 | 0.002 | |
| | | | | | | 0.010 | 0.014 | |
| | | | | | | 0.100 | 0.112 | |
| | | | | | | 1.000 | 0.870 | |
| | | | | | | 10.000 | 6.705 | |
| | | | | | | 100.000 | 50.205 | |
| 105-SM-E75 4.45 | 192. | 87. | 184. | 173. | 4.70 | | | CA,HE |
| | | | | | | 0.001 | 0.001 | |
| | | | | | | 0.010 | 0.012 | |
| | | | | | | 0.100 | 0.099 | |
| | | | | | | 1.000 | 0.842 | |
| | | | | | | 10.000 | 7.106 | |
| | | | | | | 100.000 | 59.369 | |

## PEAK SHEAR STRENGTH ESTIMATION

| SAMPLE NUMBER | STRIKE | DIP | UNIAXIAL COMP. STRENGTH (MPa) | JOINT WALL COMP. STRENGTH (MPa) | JRC | NORMAL STRESS (MPa) | SHEAR STRENGTH (MPa) | INFILLING MATERIAL |
|---|---|---|---|---|---|---|---|---|
| 105-SM-E83 8.99 | 208. | 90. | 241. | 177. | 5.90 | | | CL,HE,CY |
| | | | | | | 0.001 | 0.002 | |
| | | | | | | 0.010 | 0.013 | |
| | | | | | | 0.100 | 0.108 | |
| | | | | | | 1.000 | 0.879 | |
| | | | | | | 10.000 | 7.111 | |
| | | | | | | 100.000 | 56.610 | |
| 105-SM-S75 2.50 | 186. | 82. | 209. | 129. | 4.58 | | | CA |
| | | | | | | 0.001 | 0.001 | |
| | | | | | | 0.010 | 0.010 | |
| | | | | | | 0.100 | 0.087 | |
| | | | | | | 1.000 | 0.738 | |
| | | | | | | 10.000 | 6.214 | |
| | | | | | | 100.000 | 51.562 | |
| 105-SM-S83 1.30 | 194. | 89. | 200. | 107. | 2.99 | | | CL,PY,CA,GO |
| | | | | | | 0.001 | 0.001 | |
| | | | | | | 0.010 | 0.008 | |
| | | | | | | 0.100 | 0.070 | |
| | | | | | | 1.000 | 0.622 | |
| | | | | | | 10.000 | 5.514 | |
| | | | | | | 100.000 | 48.517 | |
| URL1 29.46 | 134. | 60. | 208. | 173. | 6.46 | | | NO |
| | | | | | | 0.001 | 0.002 | |
| | | | | | | 0.010 | 0.015 | |
| | | | | | | 0.100 | 0.118 | |
| | | | | | | 1.000 | 0.940 | |
| | | | | | | 10.000 | 7.475 | |
| | | | | | | 100.000 | 58.477 | |
| URL1 39.05 | 36. | 74. | 184. | 133. | 7.94 | | | CA,HE,CL |
| | | | | | | 0.001 | 0.003 | |
| | | | | | | 0.010 | 0.018 | |
| | | | | | | 0.100 | 0.130 | |
| | | | | | | 1.000 | 0.986 | |
| | | | | | | 10.000 | 7.440 | |
| | | | | | | 100.000 | 54.765 | |
| URL1 54.87 | 37. | 77. | 214. | 117. | 5.70 | | | HE |
| | | | | | | 0.001 | 0.001 | |
| | | | | | | 0.010 | 0.012 | |
| | | | | | | 0.100 | 0.095 | |
| | | | | | | 1.000 | 0.777 | |
| | | | | | | 10.000 | 6.285 | |
| | | | | | | 100.000 | 49.751 | |

## PEAK SHEAR STRENGTH ESTIMATION

| SAMPLE NUMBER | STRIKE | DIP | UNIAXIAL COMP. STRENGTH (MPa) | JOINT WALL COMP. STRENGTH (MPa) | JRC | NORMAL STRESS (MPa) | SHEAR STRENGTH (MPa) | INFILLING MATERIAL |
|---|---|---|---|---|---|---|---|---|
| URL1 68.73 | 38. | 74. | 222. | 49. | 8.03 | | | CA,HE |
| | | | | | | 0.001 | 0.002 | |
| | | | | | | 0.010 | 0.012 | |
| | | | | | | 0.100 | 0.090 | |
| | | | | | | 1.000 | 0.670 | |
| | | | | | | 10.000 | 4.834 | |
| | | | | | | 100.000 | 32.054 | |
| URL1 69.28 | 58. | 52. | 224. | 97. | 5.54 | | | CA,HE |
| | | | | | | 0.001 | 0.001 | |
| | | | | | | 0.010 | 0.011 | |
| | | | | | | 0.100 | 0.087 | |
| | | | | | | 1.000 | 0.715 | |
| | | | | | | 10.000 | 5.776 | |
| | | | | | | 100.000 | 45.506 | |
| URL1 86.28 | 89. | 36. | 192. | 73. | 5.23 | | | CA,HE,CY |
| | | | | | | 0.001 | 0.001 | |
| | | | | | | 0.010 | 0.010 | |
| | | | | | | 0.100 | 0.079 | |
| | | | | | | 1.000 | 0.654 | |
| | | | | | | 10.000 | 5.307 | |
| | | | | | | 100.000 | 41.869 | |
| URL1 87.87 | 45. | 83. | 222. | 135. | 7.46 | | | NO |
| | | | | | | 0.001 | 0.002 | |
| | | | | | | 0.010 | 0.016 | |
| | | | | | | 0.100 | 0.120 | |
| | | | | | | 1.000 | 0.923 | |
| | | | | | | 10.000 | 7.065 | |
| | | | | | | 100.000 | 52.687 | |
| URL1 98.67 | 37. | 77. | 147. | 147. | 6.31 | | | NO |
| | | | | | | 0.001 | 0.002 | |
| | | | | | | 0.010 | 0.015 | |
| | | | | | | 0.100 | 0.119 | |
| | | | | | | 1.000 | 0.955 | |
| | | | | | | 10.000 | 7.635 | |
| | | | | | | 100.000 | 60.220 | |
| URL1 121.72 | 37. | 69. | 156. | 156. | 5.35 | | | CA,HE |
| | | | | | | 0.001 | 0.002 | |
| | | | | | | 0.010 | 0.013 | |
| | | | | | | 0.100 | 0.108 | |
| | | | | | | 1.000 | 0.892 | |
| | | | | | | 10.000 | 7.370 | |
| | | | | | | 100.000 | 60.180 | |

PEAK SHEAR STRENGTH ESTIMATION

| SAMPLE NUMBER | STRIKE | DIP | UNIAXIAL COMP. STRENGTH (MPa) | JOINT WALL COMP. STRENGTH (MPa) | JRC | NORMAL STRESS (MPa) | SHEAR STRENGTH (MPa) | INFILLING MATERIAL |
|---|---|---|---|---|---|---|---|---|
| URL1 326.14 | 91. | 20. | 127. | 110. | 4.83 | | | HE,CL |
| | | | | | | 0.001 | 0.001 | |
| | | | | | | 0.010 | 0.011 | |
| | | | | | | 0.100 | 0.095 | |
| | | | | | | 1.000 | 0.802 | |
| | | | | | | 10.000 | 6.718 | |
| | | | | | | 100.000 | 55.588 | |
| URL1 326.59 | 121. | 60. | 127. | 45. | 5.45 | | | HE,CL |
| | | | | | | 0.001 | 0.001 | |
| | | | | | | 0.010 | 0.009 | |
| | | | | | | 0.100 | 0.073 | |
| | | | | | | 1.000 | 0.597 | |
| | | | | | | 10.000 | 4.741 | |
| | | | | | | 100.000 | 36.219 | |
| URL1 465.54 | 30. | 58. | 146. | 126. | 4.51 | | | BI |
| | | | | | | 0.001 | 0.001 | |
| | | | | | | 0.010 | 0.011 | |
| | | | | | | 0.100 | 0.093 | |
| | | | | | | 1.000 | 0.791 | |
| | | | | | | 10.000 | 6.707 | |
| | | | | | | 100.000 | 56.202 | |
| URL2 6.95 | 38. | 64. | 110. | 89. | 8.43 | | | CA,HE |
| | | | | | | 0.001 | 0.003 | |
| | | | | | | 0.010 | 0.018 | |
| | | | | | | 0.100 | 0.133 | |
| | | | | | | 1.000 | 0.987 | |
| | | | | | | 10.000 | 7.318 | |
| | | | | | | 100.000 | 52.641 | |
| URL2 81.86 | 69. | 60. | 206. | 65. | 8.43 | | | CL,BI |
| | | | | | | 0.001 | 0.002 | |
| | | | | | | 0.010 | 0.014 | |
| | | | | | | 0.100 | 0.104 | |
| | | | | | | 1.000 | 0.772 | |
| | | | | | | 10.000 | 5.596 | |
| | | | | | | 100.000 | 37.992 | |
| URL2 109.23 | 67. | 57. | 82. | 53. | 5.35 | | | CA,HE,CL |
| | | | | | | 0.001 | 0.001 | |
| | | | | | | 0.010 | 0.010 | |
| | | | | | | 0.100 | 0.085 | |
| | | | | | | 1.000 | 0.699 | |
| | | | | | | 10.000 | 5.687 | |
| | | | | | | 100.000 | 45.107 | |

## PEAK SHEAR STRENGTH ESTIMATION

| SAMPLE NUMBER | STRIKE | DIP | UNIAXIAL COMP. STRENGTH (MPa) | JOINT WALL COMP. STRENGTH (MPa) | JRC | NORMAL STRESS (MPa) | SHEAR STRENGTH (MPa) | INFILLING MATERIAL |
|---|---|---|---|---|---|---|---|---|
| URL2 115.66 | 45. | 61. | 160. | 120. | 6.42 | | | CA,HE |
| | | | | | | 0.001 | 0.002 | |
| | | | | | | 0.010 | 0.014 | |
| | | | | | | 0.100 | 0.110 | |
| | | | | | | 1.000 | 0.877 | |
| | | | | | | 10.000 | 6.958 | |
| | | | | | | 100.000 | 54.101 | |
| URL3 6.83 | 19. | 57. | 190. | 121. | 5.28 | | | CA,HE |
| | | | | | | 0.001 | 0.001 | |
| | | | | | | 0.010 | 0.011 | |
| | | | | | | 0.100 | 0.094 | |
| | | | | | | 1.000 | 0.779 | |
| | | | | | | 10.000 | 6.402 | |
| | | | | | | 100.000 | 51.724 | |
| URL3 46.59 | 217. | 71. | 208. | 127. | 7.50 | | | CL |
| | | | | | | 0.001 | 0.002 | |
| | | | | | | 0.010 | 0.016 | |
| | | | | | | 0.100 | 0.119 | |
| | | | | | | 1.000 | 0.917 | |
| | | | | | | 10.000 | 7.008 | |
| | | | | | | 100.000 | 52.109 | |
| URL3 58.66 | 192. | 61. | 175. | 120. | 6.17 | | | NO |
| | | | | | | 0.001 | 0.002 | |
| | | | | | | 0.010 | 0.013 | |
| | | | | | | 0.100 | 0.105 | |
| | | | | | | 1.000 | 0.844 | |
| | | | | | | 10.000 | 6.741 | |
| | | | | | | 100.000 | 52.752 | |
| URL3 65.59 | 13. | 24. | 149. | 94. | 6.40 | | | HE,CY |
| | | | | | | 0.001 | 0.002 | |
| | | | | | | 0.010 | 0.013 | |
| | | | | | | 0.100 | 0.102 | |
| | | | | | | 1.000 | 0.815 | |
| | | | | | | 10.000 | 6.438 | |
| | | | | | | 100.000 | 49.575 | |
| URL5 65.76 | 291. | 80. | 198. | 137. | 6.61 | | | NO |
| | | | | | | 0.001 | 0.002 | |
| | | | | | | 0.010 | 0.014 | |
| | | | | | | 0.100 | 0.112 | |
| | | | | | | 1.000 | 0.889 | |
| | | | | | | 10.000 | 7.006 | |
| | | | | | | 100.000 | 54.091 | |

## PEAK SHEAR STRENGTH ESTIMATION

| SAMPLE NUMBER | STRIKE | DIP | UNIAXIAL COMP. STRENGTH (MPa) | JOINT WALL COMP. STRENGTH (MPa) | JRC | NORMAL STRESS (MPa) | SHEAR STRENGTH (MPa) | INFILLING MATERIAL |
|---|---|---|---|---|---|---|---|---|
| URL5 91.65 | 127. | 38. | 222. | 196. | 5.32 | | | HE,CL |
| | | | | | | 0.001 | 0.002 | |
| | | | | | | 0.010 | 0.013 | |
| | | | | | | 0.100 | 0.106 | |
| | | | | | | 1.000 | 0.882 | |
| | | | | | | 10.000 | 7.286 | |
| | | | | | | 100.000 | 59.506 | |
| URL5 106.24 | 352. | 58. | 175. | 137. | 8.31 | | | BI,PY |
| | | | | | | 0.001 | 0.003 | |
| | | | | | | 0.010 | 0.019 | |
| | | | | | | 0.100 | 0.139 | |
| | | | | | | 1.000 | 1.036 | |
| | | | | | | 10.000 | 7.731 | |
| | | | | | | 100.000 | 56.347 | |
| URL5 211.10 | 42. | 24. | 135. | 135. | 5.71 | | | NO |
| | | | | | | 0.001 | 0.002 | |
| | | | | | | 0.010 | 0.014 | |
| | | | | | | 0.100 | 0.111 | |
| | | | | | | 1.000 | 0.905 | |
| | | | | | | 10.000 | 7.386 | |
| | | | | | | 100.000 | 59.471 | |
| URL5 216.40 | 347. | 23. | 176. | 152. | 6.18 | | | NO |
| | | | | | | 0.001 | 0.002 | |
| | | | | | | 0.010 | 0.014 | |
| | | | | | | 0.100 | 0.114 | |
| | | | | | | 1.000 | 0.916 | |
| | | | | | | 10.000 | 7.346 | |
| | | | | | | 100.000 | 58.021 | |
| URL5 223.01 | 11. | 53. | 184. | 131. | 5.31 | | | HE |
| | | | | | | 0.001 | 0.001 | |
| | | | | | | 0.010 | 0.012 | |
| | | | | | | 0.100 | 0.097 | |
| | | | | | | 1.000 | 0.807 | |
| | | | | | | 10.000 | 6.642 | |
| | | | | | | 100.000 | 53.819 | |
| URL5 232.03 | 37. | 52. | 196. | 134. | 8.41 | | | HE,CL |
| | | | | | | 0.001 | 0.003 | |
| | | | | | | 0.010 | 0.019 | |
| | | | | | | 0.100 | 0.136 | |
| | | | | | | 1.000 | 1.012 | |
| | | | | | | 10.000 | 7.513 | |
| | | | | | | 100.000 | 54.302 | |

## PEAK SHEAR STRENGTH ESTIMATION

| SAMPLE NUMBER | STRIKE | DIP | UNIAXIAL COMP. STRENGTH (MPa) | JOINT WALL COMP. STRENGTH (MPa) | JRC | NORMAL STRESS (MPa) | SHEAR STRENGTH (MPa) | INFILLING MATERIAL |
|---|---|---|---|---|---|---|---|---|
| URL5 257.89 | 2. | 78. | 214. | 62. | 8.11 | | | CA,HE,SR |
| | | | | | | 0.001 | 0.002 | |
| | | | | | | 0.010 | 0.013 | |
| | | | | | | 0.100 | 0.098 | |
| | | | | | | 1.000 | 0.736 | |
| | | | | | | 10.000 | 5.375 | |
| | | | | | | 100.000 | 36.685 | |
| URL5 258.63 | 61. | 23. | 176. | 89. | 3.50 | | | HE,CL,CY,QTZ |
| | | | | | | 0.001 | 0.001 | |
| | | | | | | 0.010 | 0.008 | |
| | | | | | | 0.100 | 0.071 | |
| | | | | | | 1.000 | 0.625 | |
| | | | | | | 10.000 | 5.435 | |
| | | | | | | 100.000 | 46.695 | |
| URL5 261.60 | 332. | 68. | 129. | 123. | 8.80 | | | NO |
| | | | | | | 0.001 | 0.004 | |
| | | | | | | 0.010 | 0.022 | |
| | | | | | | 0.100 | 0.153 | |
| | | | | | | 1.000 | 1.112 | |
| | | | | | | 10.000 | 8.163 | |
| | | | | | | 100.000 | 58.727 | |
| URL6 14.52 | 323. | 82. | 248. | 119. | 7.53 | | | HE,CL |
| | | | | | | 0.001 | 0.002 | |
| | | | | | | 0.010 | 0.015 | |
| | | | | | | 0.100 | 0.113 | |
| | | | | | | 1.000 | 0.871 | |
| | | | | | | 10.000 | 6.622 | |
| | | | | | | 100.000 | 48.722 | |
| URL6 85.70 | N/A | N/A | 237. | 127. | 8.35 | | | NO |
| | | | | | | 0.001 | 0.003 | |
| | | | | | | 0.010 | 0.018 | |
| | | | | | | 0.100 | 0.128 | |
| | | | | | | 1.000 | 0.953 | |
| | | | | | | 10.000 | 7.075 | |
| | | | | | | 100.000 | 50.800 | |
| URL6 98.61 | 230. | 13. | 222. | 170. | 4.30 | | | HE |
| | | | | | | 0.001 | 0.001 | |
| | | | | | | 0.010 | 0.011 | |
| | | | | | | 0.100 | 0.090 | |
| | | | | | | 1.000 | 0.777 | |
| | | | | | | 10.000 | 6.632 | |
| | | | | | | 100.000 | 56.012 | |

PEAK SHEAR STRENGTH ESTIMATION

| SAMPLE NUMBER | STRIKE | DIP | UNIAXIAL COMP. STRENGTH (MPa) | JOINT WALL COMP. STRENGTH (MPa) | JRC | NORMAL STRESS (MPa) | SHEAR STRENGTH (MPa) | INFILLING MATERIAL |
|---|---|---|---|---|---|---|---|---|
| URL6 98.71 | 325. | 43. | 184. | 184. | 3.67 | | | CA,HE |
| | | | | | | 0.001 | 0.001 | |
| | | | | | | 0.010 | 0.010 | |
| | | | | | | 0.100 | 0.090 | |
| | | | | | | 1.000 | 0.790 | |
| | | | | | | 10.000 | 6.911 | |
| | | | | | | 100.000 | 60.028 | |
| URL6 99.00 | 15. | 85. | 241. | 179. | 6.67 | | | HE,CL,CY |
| | | | | | | 0.001 | 0.002 | |
| | | | | | | 0.010 | 0.015 | |
| | | | | | | 0.100 | 0.118 | |
| | | | | | | 1.000 | 0.937 | |
| | | | | | | 10.000 | 7.391 | |
| | | | | | | 100.000 | 57.267 | |
| URL6 113.00 | 355. | 78. | 222. | 172. | 6.64 | | | CA,HE |
| | | | | | | 0.001 | 0.002 | |
| | | | | | | 0.010 | 0.015 | |
| | | | | | | 0.100 | 0.118 | |
| | | | | | | 1.000 | 0.938 | |
| | | | | | | 10.000 | 7.408 | |
| | | | | | | 100.000 | 57.478 | |
| URL6 207.29 | 200. | 22. | 197. | 147. | 5.67 | | | HE |
| | | | | | | 0.001 | 0.002 | |
| | | | | | | 0.010 | 0.013 | |
| | | | | | | 0.100 | 0.104 | |
| | | | | | | 1.000 | 0.849 | |
| | | | | | | 10.000 | 6.911 | |
| | | | | | | 100.000 | 55.373 | |
| URL6 216.09 | 325. | 59. | 218. | 165. | 7.67 | | | HE,CL |
| | | | | | | 0.001 | 0.003 | |
| | | | | | | 0.010 | 0.018 | |
| | | | | | | 0.100 | 0.132 | |
| | | | | | | 1.000 | 1.007 | |
| | | | | | | 10.000 | 7.684 | |
| | | | | | | 100.000 | 57.430 | |
| URL7 142.56 | 344. | 79. | 138. | 94. | 5.52 | | | CA,HE |
| | | | | | | 0.001 | 0.001 | |
| | | | | | | 0.010 | 0.011 | |
| | | | | | | 0.100 | 0.095 | |
| | | | | | | 1.000 | 0.778 | |
| | | | | | | 10.000 | 6.340 | |
| | | | | | | 100.000 | 50.626 | |

## PEAK SHEAR STRENGTH ESTIMATION

| SAMPLE NUMBER | STRIKE | DIP | UNIAXIAL COMP. STRENGTH (MPa) | JOINT WALL COMP. STRENGTH (MPa) | JRC | NORMAL STRESS (MPa) | SHEAR STRENGTH (MPa) | INFILLING MATERIAL |
|---|---|---|---|---|---|---|---|---|
| URL7 144.60 | 123. | 60. | 165. | 112. | 7.44 | | | CA,HE |
| | | | | | | 0.001 | 0.002 | |
| | | | | | | 0.010 | 0.016 | |
| | | | | | | 0.100 | 0.119 | |
| | | | | | | 1.000 | 0.914 | |
| | | | | | | 10.000 | 6.999 | |
| | | | | | | 100.000 | 52.162 | |
| URL7 153.24 | 343. | 69. | 149. | 70. | 8.78 | | | HE,CY |
| | | | | | | 0.001 | 0.002 | |
| | | | | | | 0.010 | 0.016 | |
| | | | | | | 0.100 | 0.116 | |
| | | | | | | 1.000 | 0.854 | |
| | | | | | | 10.000 | 6.183 | |
| | | | | | | 100.000 | 42.337 | |

Table 3 - Joint sample properties: Estimated joint roughness coefficient (JRC)

PEAK SHEAR STRENGTH ESTIMATION

| SAMPLE NUMBER | STRIKE | DIP | UNIAXIAL COMP. STRENGTH (MPa) | JOINT WALL COMP. STRENGTH (MPa) | JRC ESTIMATE | NORMAL STRESS (MPa) | SHEAR STRENGTH (MPa) | INFILLING MATERIAL |
|---|---|---|---|---|---|---|---|---|
| URL1 49.94 | 69. | 74. | 222. | 117. | 5.5 | | | CL |
| | | | | | | 0.001 | 0.001 | |
| | | | | | | 0.010 | 0.011 | |
| | | | | | | 0.100 | 0.092 | |
| | | | | | | 1.000 | 0.759 | |
| | | | | | | 10.000 | 6.177 | |
| | | | | | | 100.000 | 49.214 | |
| URL1 69.03 | 56. | 46. | 222. | 99. | 7.0 | | | CA,HE |
| | | | | | | 0.001 | 0.002 | |
| | | | | | | 0.010 | 0.013 | |
| | | | | | | 0.100 | 0.102 | |
| | | | | | | 1.000 | 0.801 | |
| | | | | | | 10.000 | 6.174 | |
| | | | | | | 100.000 | 45.975 | |
| URL1 77.08 | 151. | 51. | 190. | 155. | 7.0 | | | CY,HE |
| | | | | | | 0.001 | 0.002 | |
| | | | | | | 0.010 | 0.016 | |
| | | | | | | 0.100 | 0.123 | |
| | | | | | | 1.000 | 0.963 | |
| | | | | | | 10.000 | 7.515 | |
| | | | | | | 100.000 | 57.561 | |
| URL1 103.51 | 316. | 41. | 168. | 115. | 5.0 | | | CA,CH |
| | | | | | | 0.001 | 0.001 | |
| | | | | | | 0.010 | 0.011 | |
| | | | | | | 0.100 | 0.092 | |
| | | | | | | 1.000 | 0.770 | |
| | | | | | | 10.000 | 6.393 | |
| | | | | | | 100.000 | 52.263 | |
| URL1 109.50 | 54. | 65. | 158. | 73. | 8.5 | | | CA,HE |
| | | | | | | 0.001 | 0.002 | |
| | | | | | | 0.010 | 0.016 | |
| | | | | | | 0.100 | 0.114 | |
| | | | | | | 1.000 | 0.846 | |
| | | | | | | 10.000 | 6.184 | |
| | | | | | | 100.000 | 42.928 | |
| URL1 123.47 | 28. | 87. | 133. | 120. | 8.5 | | | CA,HE |
| | | | | | | 0.001 | 0.003 | |
| | | | | | | 0.010 | 0.020 | |
| | | | | | | 0.100 | 0.145 | |
| | | | | | | 1.000 | 1.067 | |
| | | | | | | 10.000 | 7.917 | |
| | | | | | | 100.000 | 57.426 | |

## PEAK SHEAR STRENGTH ESTIMATION

| SAMPLE NUMBER | STRIKE | DIP | UNIAXIAL COMP. STRENGTH (MPa) | JOINT WALL COMP. STRENGTH (MPa) | JRC ESTIMATE | NORMAL STRESS (MPa) | SHEAR STRENGTH (MPa) | INFILLING MATERIAL |
|---|---|---|---|---|---|---|---|---|
| URL1 142.93 | 37. | 87. | 173. | 150. | 5.0 | | | CL,HE |
| | | | | | | 0.001 | 0.001 | |
| | | | | | | 0.010 | 0.012 | |
| | | | | | | 0.100 | 0.100 | |
| | | | | | | 1.000 | 0.835 | |
| | | | | | | 10.000 | 6.968 | |
| | | | | | | 100.000 | 57.427 | |
| URL1 151.27 | 18. | 78. | 158. | 98. | 5.0 | | | BI |
| | | | | | | 0.001 | 0.001 | |
| | | | | | | 0.010 | 0.011 | |
| | | | | | | 0.100 | 0.088 | |
| | | | | | | 1.000 | 0.738 | |
| | | | | | | 10.000 | 6.110 | |
| | | | | | | 100.000 | 49.698 | |
| URL1 151.40 | 53. | 65. | 158. | 129. | 4.5 | | | NO |
| | | | | | | 0.001 | 0.001 | |
| | | | | | | 0.010 | 0.011 | |
| | | | | | | 0.100 | 0.092 | |
| | | | | | | 1.000 | 0.781 | |
| | | | | | | 10.000 | 6.618 | |
| | | | | | | 100.000 | 55.420 | |
| URL1 325.40 | 140. | 46. | 173. | 127. | 4.0 | | | NO |
| | | | | | | 0.001 | 0.001 | |
| | | | | | | 0.010 | 0.010 | |
| | | | | | | 0.100 | 0.085 | |
| | | | | | | 1.000 | 0.733 | |
| | | | | | | 10.000 | 6.309 | |
| | | | | | | 100.000 | 53.725 | |
| URL1 325.86 | 87. | 58. | 127. | 85. | 6.0 | | | CL,BI |
| | | | | | | 0.001 | 0.002 | |
| | | | | | | 0.010 | 0.012 | |
| | | | | | | 0.100 | 0.098 | |
| | | | | | | 1.000 | 0.790 | |
| | | | | | | 10.000 | 6.324 | |
| | | | | | | 100.000 | 49.446 | |
| URL1 328.74 | 134. | 44. | 147. | 147. | 8.5 | | | NO |
| | | | | | | 0.001 | 0.003 | |
| | | | | | | 0.010 | 0.022 | |
| | | | | | | 0.100 | 0.154 | |
| | | | | | | 1.000 | 1.127 | |
| | | | | | | 10.000 | 8.368 | |
| | | | | | | 100.000 | 61.098 | |

PEAK SHEAR STRENGTH ESTIMATION

| SAMPLE NUMBER | STRIKE | DIP | UNIAXIAL COMP. STRENGTH (MPa) | JOINT WALL COMP. STRENGTH (MPa) | JRC ESTIMATE | NORMAL STRESS (MPa) | SHEAR STRENGTH (MPa) | INFILLING MATERIAL |
|---|---|---|---|---|---|---|---|---|
| URL1 330.63 | 177. | 31. | 89. | 45. | 4.5 | | | CL, BI |
| | | | | | | 0.001 | 0.001 | |
| | | | | | | 0.010 | 0.008 | |
| | | | | | | 0.100 | 0.072 | |
| | | | | | | 1.000 | 0.603 | |
| | | | | | | 10.000 | 5.003 | |
| | | | | | | 100.000 | 40.563 | |
| URL1 330.92 | 210. | 34. | 166. | 166. | 5.0 | | | HE |
| | | | | | | 0.001 | 0.001 | |
| | | | | | | 0.010 | 0.012 | |
| | | | | | | 0.100 | 0.104 | |
| | | | | | | 1.000 | 0.873 | |
| | | | | | | 10.000 | 7.293 | |
| | | | | | | 100.000 | 60.335 | |
| URL2 18.75 | 153. | 81. | 175. | 86. | 7.0 | | | HE |
| | | | | | | 0.001 | 0.002 | |
| | | | | | | 0.010 | 0.013 | |
| | | | | | | 0.100 | 0.102 | |
| | | | | | | 1.000 | 0.797 | |
| | | | | | | 10.000 | 6.145 | |
| | | | | | | 100.000 | 45.721 | |
| URL2 48.30 | 37. | 44. | 163. | 64. | 6.0 | | | CY, PEGMATITE |
| | | | | | | 0.001 | 0.001 | |
| | | | | | | 0.010 | 0.010 | |
| | | | | | | 0.100 | 0.084 | |
| | | | | | | 1.000 | 0.677 | |
| | | | | | | 10.000 | 5.340 | |
| | | | | | | 100.000 | 40.607 | |
| URL2 68.52 | 159. | 43. | 122. | 77. | 4.5 | | | CA, BI |
| | | | | | | 0.001 | 0.001 | |
| | | | | | | 0.010 | 0.010 | |
| | | | | | | 0.100 | 0.082 | |
| | | | | | | 1.000 | 0.694 | |
| | | | | | | 10.000 | 5.837 | |
| | | | | | | 100.000 | 48.283 | |
| URL2 79.79 | 18. | 66. | 211. | 80. | 6.5 | | | CA, HE |
| | | | | | | 0.001 | 0.001 | |
| | | | | | | 0.010 | 0.011 | |
| | | | | | | 0.100 | 0.091 | |
| | | | | | | 1.000 | 0.724 | |
| | | | | | | 10.000 | 5.637 | |
| | | | | | | 100.000 | 42.266 | |

## PEAK SHEAR STRENGTH ESTIMATION

| SAMPLE NUMBER | STRIKE | DIP | UNIAXIAL COMP. STRENGTH (MPa) | JOINT WALL COMP. STRENGTH (MPa) | JRC ESTIMATE | NORMAL STRESS (MPa) | SHEAR STRENGTH (MPa) | INFILLING MATERIAL |
|---|---|---|---|---|---|---|---|---|
| URL2 93.97 | 245. | 15. | 188. | 96. | 5.0 | | | HE |
| | | | | | | 0.001 | 0.001 | |
| | | | | | | 0.010 | 0.010 | |
| | | | | | | 0.100 | 0.085 | |
| | | | | | | 1.000 | 0.707 | |
| | | | | | | 10.000 | 5.833 | |
| | | | | | | 100.000 | 47.173 | |
| URL2 99.80 | 53. | 83. | 219. | 114. | 7.0 | | | CA,BI |
| | | | | | | 0.001 | 0.002 | |
| | | | | | | 0.010 | 0.014 | |
| | | | | | | 0.100 | 0.108 | |
| | | | | | | 1.000 | 0.842 | |
| | | | | | | 10.000 | 6.522 | |
| | | | | | | 100.000 | 49.017 | |
| URL2 101.72 | 125. | 75. | 217. | 105. | 6.5 | | | CA,HE |
| | | | | | | 0.001 | 0.002 | |
| | | | | | | 0.010 | 0.013 | |
| | | | | | | 0.100 | 0.100 | |
| | | | | | | 1.000 | 0.792 | |
| | | | | | | 10.000 | 6.217 | |
| | | | | | | 100.000 | 47.417 | |
| URL2 111.49 | 59. | 56. | 87. | 58. | 5.0 | | | CL,CA,BI |
| | | | | | | 0.001 | 0.001 | |
| | | | | | | 0.010 | 0.010 | |
| | | | | | | 0.100 | 0.084 | |
| | | | | | | 1.000 | 0.703 | |
| | | | | | | 10.000 | 5.797 | |
| | | | | | | 100.000 | 46.848 | |
| URL2 114.27 | 69. | 64. | 184. | 116. | 9.0 | | | CA,HE |
| | | | | | | 0.001 | 0.003 | |
| | | | | | | 0.010 | 0.020 | |
| | | | | | | 0.100 | 0.140 | |
| | | | | | | 1.000 | 1.014 | |
| | | | | | | 10.000 | 7.371 | |
| | | | | | | 100.000 | 51.823 | |
| URL2 163.51 | 0. | 53. | 165. | 76. | 4.5 | | | CL,BI |
| | | | | | | 0.001 | 0.001 | |
| | | | | | | 0.010 | 0.009 | |
| | | | | | | 0.100 | 0.077 | |
| | | | | | | 1.000 | 0.648 | |
| | | | | | | 10.000 | 5.415 | |
| | | | | | | 100.000 | 44.390 | |

PEAK SHEAR STRENGTH ESTIMATION

| SAMPLE | NUMBER | STRIKE | DIP | UNIAXIAL COMP. STRENGTH (MPa) | JOINT WALL COMP. STRENGTH (MPa) | JRC ESTIMATE | NORMAL STRESS (MPa) | SHEAR STRENGTH (MPa) | INFILLING MATERIAL |
|---|---|---|---|---|---|---|---|---|---|
| URL3 | 5.91 | 77. | 52. | 181. | 89. | 7.0 | | | CL, BI |
| | | | | | | | 0.001 | 0.002 | |
| | | | | | | | 0.010 | 0.013 | |
| | | | | | | | 0.100 | 0.103 | |
| | | | | | | | 1.000 | 0.802 | |
| | | | | | | | 10.000 | 6.180 | |
| | | | | | | | 100.000 | 46.031 | |
| URL3 | 19.71 | 209. | 66. | 200. | 120. | 5.5 | | | HE |
| | | | | | | | 0.001 | 0.001 | |
| | | | | | | | 0.010 | 0.011 | |
| | | | | | | | 0.100 | 0.095 | |
| | | | | | | | 1.000 | 0.781 | |
| | | | | | | | 10.000 | 6.367 | |
| | | | | | | | 100.000 | 50.916 | |
| URL3 | 25.27 | 208. | 77. | 143. | 122. | 8.0 | | | HE |
| | | | | | | | 0.001 | 0.003 | |
| | | | | | | | 0.010 | 0.018 | |
| | | | | | | | 0.100 | 0.135 | |
| | | | | | | | 1.000 | 1.019 | |
| | | | | | | | 10.000 | 7.682 | |
| | | | | | | | 100.000 | 56.650 | |
| URL3 | 35.12 | 196. | 66. | 194. | 103. | 8.0 | | | NO |
| | | | | | | | 0.001 | 0.002 | |
| | | | | | | | 0.010 | 0.016 | |
| | | | | | | | 0.100 | 0.118 | |
| | | | | | | | 1.000 | 0.893 | |
| | | | | | | | 10.000 | 6.688 | |
| | | | | | | | 100.000 | 48.284 | |
| URL3 | 61.75 | 242. | 59. | 198. | 70. | 6.0 | | | BI |
| | | | | | | | 0.001 | 0.001 | |
| | | | | | | | 0.010 | 0.010 | |
| | | | | | | | 0.100 | 0.084 | |
| | | | | | | | 1.000 | 0.674 | |
| | | | | | | | 10.000 | 5.316 | |
| | | | | | | | 100.000 | 40.395 | |
| URL3 | 62.13 | 261. | 51. | 175. | 110. | 5.5 | | | BI |
| | | | | | | | 0.001 | 0.001 | |
| | | | | | | | 0.010 | 0.011 | |
| | | | | | | | 0.100 | 0.095 | |
| | | | | | | | 1.000 | 0.781 | |
| | | | | | | | 10.000 | 6.367 | |
| | | | | | | | 100.000 | 50.923 | |

## PEAK SHEAR STRENGTH ESTIMATION

| SAMPLE NUMBER | STRIKE | DIP | UNIAXIAL COMP. STRENGTH (MPa) | JOINT WALL COMP. STRENGTH (MPa) | JRC ESTIMATE | NORMAL STRESS (MPa) | SHEAR STRENGTH (MPa) | INFILLING MATERIAL |
|---|---|---|---|---|---|---|---|---|
| URL3 64.76 | 313. | 31. | 197. | 109. | 4.0 | | | CY,HE |
| | | | | | | 0.001 | 0.001 | |
| | | | | | | 0.010 | 0.009 | |
| | | | | | | 0.100 | 0.079 | |
| | | | | | | 1.000 | 0.679 | |
| | | | | | | 10.000 | 5.813 | |
| | | | | | | 100.000 | 49.136 | |
| URL3 65.92 | 337. | 21. | 134. | 98. | 7.5 | | | CY,HE |
| | | | | | | 0.001 | 0.002 | |
| | | | | | | 0.010 | 0.016 | |
| | | | | | | 0.100 | 0.119 | |
| | | | | | | 1.000 | 0.915 | |
| | | | | | | 10.000 | 6.989 | |
| | | | | | | 100.000 | 51.947 | |
| URL3 66.42 | 41. | 38. | 181. | 99. | 6.0 | | | CA,HE |
| | | | | | | 0.001 | 0.001 | |
| | | | | | | 0.010 | 0.012 | |
| | | | | | | 0.100 | 0.096 | |
| | | | | | | 1.000 | 0.774 | |
| | | | | | | 10.000 | 6.188 | |
| | | | | | | 100.000 | 48.232 | |
| URL3 67.22 | 333. | 24. | 196. | 107. | 4.5 | | | HE |
| | | | | | | 0.001 | 0.001 | |
| | | | | | | 0.010 | 0.010 | |
| | | | | | | 0.100 | 0.083 | |
| | | | | | | 1.000 | 0.701 | |
| | | | | | | 10.000 | 5.899 | |
| | | | | | | 100.000 | 48.850 | |
| URL3 89.53 | 15. | 19. | 173. | 98. | 4.5 | | | QZ,HE |
| | | | | | | 0.001 | 0.001 | |
| | | | | | | 0.010 | 0.010 | |
| | | | | | | 0.100 | 0.082 | |
| | | | | | | 1.000 | 0.697 | |
| | | | | | | 10.000 | 5.866 | |
| | | | | | | 100.000 | 48.546 | |
| URL3 102.06 | 61. | 16. | 166. | 114. | 5.0 | | | HE |
| | | | | | | 0.001 | 0.001 | |
| | | | | | | 0.010 | 0.011 | |
| | | | | | | 0.100 | 0.092 | |
| | | | | | | 1.000 | 0.769 | |
| | | | | | | 10.000 | 6.386 | |
| | | | | | | 100.000 | 52.191 | |

## PEAK SHEAR STRENGTH ESTIMATION

| SAMPLE NUMBER | STRIKE | DIP | UNIAXIAL COMP. STRENGTH (MPa) | JOINT WALL COMP. STRENGTH (MPa) | JRC ESTIMATE | NORMAL STRESS (MPa) | SHEAR STRENGTH (MPa) | INFILLING MATERIAL |
|---|---|---|---|---|---|---|---|---|
| URL3 102.61 | 83. | 14. | 204. | 125. | 6.0 | | | HE |
| | | | | | | 0.001 | 0.002 | |
| | | | | | | 0.010 | 0.012 | |
| | | | | | | 0.100 | 0.101 | |
| | | | | | | 1.000 | 0.818 | |
| | | | | | | 10.000 | 6.566 | |
| | | | | | | 100.000 | 51.592 | |
| URL3 107.12 | 7. | 19. | 182. | 140. | 8.5 | | | HE |
| | | | | | | 0.001 | 0.003 | |
| | | | | | | 0.010 | 0.020 | |
| | | | | | | 0.100 | 0.142 | |
| | | | | | | 1.000 | 1.050 | |
| | | | | | | 10.000 | 7.780 | |
| | | | | | | 100.000 | 56.311 | |
| URL3 114.83 | 84. | 13. | 173. | 107. | 6.0 | | | NO |
| | | | | | | 0.001 | 0.002 | |
| | | | | | | 0.010 | 0.012 | |
| | | | | | | 0.100 | 0.099 | |
| | | | | | | 1.000 | 0.803 | |
| | | | | | | 10.000 | 6.437 | |
| | | | | | | 100.000 | 50.451 | |
| URL3 124.02 | 14. | 33. | 138. | 119. | 6.5 | | | NO |
| | | | | | | 0.001 | 0.002 | |
| | | | | | | 0.010 | 0.014 | |
| | | | | | | 0.100 | 0.114 | |
| | | | | | | 1.000 | 0.911 | |
| | | | | | | 10.000 | 7.222 | |
| | | | | | | 100.000 | 56.203 | |
| URL3 305.10 | 119. | 28. | 181. | 105. | 4.0 | | | CL,BI |
| | | | | | | 0.001 | 0.001 | |
| | | | | | | 0.010 | 0.009 | |
| | | | | | | 0.100 | 0.079 | |
| | | | | | | 1.000 | 0.683 | |
| | | | | | | 10.000 | 5.853 | |
| | | | | | | 100.000 | 49.513 | |
| URL4 20.53 | 58. | 81. | 156. | 110. | 8.0 | | | NO |
| | | | | | | 0.001 | 0.002 | |
| | | | | | | 0.010 | 0.017 | |
| | | | | | | 0.100 | 0.127 | |
| | | | | | | 1.000 | 0.959 | |
| | | | | | | 10.000 | 7.209 | |
| | | | | | | 100.000 | 52.694 | |

## PEAK SHEAR STRENGTH ESTIMATION

| SAMPLE NUMBER | STRIKE | DIP | UNIAXIAL COMP. STRENGTH (MPa) | JOINT WALL COMP. STRENGTH (MPa) | JRC ESTIMATE | NORMAL STRESS (MPa) | SHEAR STRENGTH (MPa) | INFILLING MATERIAL |
|---|---|---|---|---|---|---|---|---|
| URL4 23.58 | 184. | 49. | 166. | 146. | 7.0 | | | CL,HE |
| | | | | | | 0.001 | 0.002 | |
| | | | | | | 0.010 | 0.016 | |
| | | | | | | 0.100 | 0.124 | |
| | | | | | | 1.000 | 0.972 | |
| | | | | | | 10.000 | 7.586 | |
| | | | | | | 100.000 | 58.168 | |
| URL4 36.60 | N/A | N/A | 100. | 70. | 5.0 | | | HE |
| | | | | | | 0.001 | 0.001 | |
| | | | | | | 0.010 | 0.010 | |
| | | | | | | 0.100 | 0.087 | |
| | | | | | | 1.000 | 0.731 | |
| | | | | | | 10.000 | 6.049 | |
| | | | | | | 100.000 | 49.145 | |
| URL4 36.95 | 63. | 66. | 144. | 92. | 7.0 | | | CA |
| | | | | | | 0.001 | 0.002 | |
| | | | | | | 0.010 | 0.014 | |
| | | | | | | 0.100 | 0.108 | |
| | | | | | | 1.000 | 0.849 | |
| | | | | | | 10.000 | 6.576 | |
| | | | | | | 100.000 | 49.484 | |
| URL4 37.50 | 58. | 72. | 153. | 56. | 4.5 | | | CA |
| | | | | | | 0.001 | 0.001 | |
| | | | | | | 0.010 | 0.008 | |
| | | | | | | 0.100 | 0.070 | |
| | | | | | | 1.000 | 0.588 | |
| | | | | | | 10.000 | 4.866 | |
| | | | | | | 100.000 | 39.283 | |
| URL4 49.38 | 71. | 80. | 177. | 127. | 9.0 | | | CA |
| | | | | | | 0.001 | 0.003 | |
| | | | | | | 0.010 | 0.021 | |
| | | | | | | 0.100 | 0.146 | |
| | | | | | | 1.000 | 1.059 | |
| | | | | | | 10.000 | 7.713 | |
| | | | | | | 100.000 | 54.623 | |
| URL4 51.38 | 198. | 76. | 186. | 115. | 8.0 | | | CL,HE |
| | | | | | | 0.001 | 0.002 | |
| | | | | | | 0.010 | 0.017 | |
| | | | | | | 0.100 | 0.124 | |
| | | | | | | 1.000 | 0.938 | |
| | | | | | | 10.000 | 7.045 | |
| | | | | | | 100.000 | 51.313 | |

## PEAK SHEAR STRENGTH ESTIMATION

| SAMPLE NUMBER | STRIKE | DIP | UNIAXIAL COMP. STRENGTH (MPa) | JOINT WALL COMP. STRENGTH (MPa) | JRC ESTIMATE | NORMAL STRESS (MPa) | SHEAR STRENGTH (MPa) | INFILLING MATERIAL |
|---|---|---|---|---|---|---|---|---|
| URL4 70.51 | 44. | 16. | 146. | 48. | 3.5 | | | SR,HE |
| | | | | | | 0.001 | 0.001 | |
| | | | | | | 0.010 | 0.007 | |
| | | | | | | 0.100 | 0.060 | |
| | | | | | | 1.000 | 0.520 | |
| | | | | | | 10.000 | 4.443 | |
| | | | | | | 100.000 | 37.300 | |
| URL4 70.65 | 42. | 16. | 146. | 71. | 4.5 | | | CY,HE |
| | | | | | | 0.001 | 0.001 | |
| | | | | | | 0.010 | 0.009 | |
| | | | | | | 0.100 | 0.077 | |
| | | | | | | 1.000 | 0.648 | |
| | | | | | | 10.000 | 5.413 | |
| | | | | | | 100.000 | 44.368 | |
| URL4 74.97 | 356. | 90. | 146. | 85. | 6.5 | | | CA,HE |
| | | | | | | 0.001 | 0.002 | |
| | | | | | | 0.010 | 0.013 | |
| | | | | | | 0.100 | 0.100 | |
| | | | | | | 1.000 | 0.797 | |
| | | | | | | 10.000 | 6.258 | |
| | | | | | | 100.000 | 47.783 | |
| URL4 80.27 | 147. | 2. | 141. | 77. | 7.5 | | | HE |
| | | | | | | 0.001 | 0.002 | |
| | | | | | | 0.010 | 0.014 | |
| | | | | | | 0.100 | 0.107 | |
| | | | | | | 1.000 | 0.826 | |
| | | | | | | 10.000 | 6.259 | |
| | | | | | | 100.000 | 45.664 | |
| URL4 86.63 | 67. | 8. | 126. | 81. | 4.5 | | | CY,HE |
| | | | | | | 0.001 | 0.001 | |
| | | | | | | 0.010 | 0.010 | |
| | | | | | | 0.100 | 0.083 | |
| | | | | | | 1.000 | 0.702 | |
| | | | | | | 10.000 | 5.910 | |
| | | | | | | 100.000 | 48.950 | |
| URL4 86.87 | 348. | 42. | 126. | 85. | 6.0 | | | NO |
| | | | | | | 0.001 | 0.002 | |
| | | | | | | 0.010 | 0.012 | |
| | | | | | | 0.100 | 0.098 | |
| | | | | | | 1.000 | 0.795 | |
| | | | | | | 10.000 | 6.368 | |
| | | | | | | 100.000 | 49.831 | |

## PEAK SHEAR STRENGTH ESTIMATION

| SAMPLE NUMBER | STRIKE | DIP | UNIAXIAL COMP. STRENGTH (MPa) | JOINT WALL COMP. STRENGTH (MPa) | JRC ESTIMATE | NORMAL STRESS (MPa) | SHEAR STRENGTH (MPa) | INFILLING MATERIAL |
|---|---|---|---|---|---|---|---|---|
| URL4 87.58 | 45. | 11. | 158. | 80. | 4.5 | | | CY,HE |
| | | | | | | 0.001 | 0.001 | |
| | | | | | | 0.010 | 0.009 | |
| | | | | | | 0.100 | 0.078 | |
| | | | | | | 1.000 | 0.665 | |
| | | | | | | 10.000 | 5.572 | |
| | | | | | | 100.000 | 45.843 | |
| URL5 99.52 | 240. | 82. | 211. | 112. | 8.0 | | | SR,HE |
| | | | | | | 0.001 | 0.002 | |
| | | | | | | 0.010 | 0.016 | |
| | | | | | | 0.100 | 0.120 | |
| | | | | | | 1.000 | 0.906 | |
| | | | | | | 10.000 | 6.790 | |
| | | | | | | 100.000 | 49.152 | |
| URL5 102.12 | 202. | 20. | 172. | 108. | 6.0 | | | CL,HE |
| | | | | | | 0.001 | 0.002 | |
| | | | | | | 0.010 | 0.012 | |
| | | | | | | 0.100 | 0.100 | |
| | | | | | | 1.000 | 0.808 | |
| | | | | | | 10.000 | 6.477 | |
| | | | | | | 100.000 | 50.801 | |
| URL5 103.85 | 91. | 16. | 169. | 79. | 5.5 | | | CL,BI |
| | | | | | | 0.001 | 0.001 | |
| | | | | | | 0.010 | 0.010 | |
| | | | | | | 0.100 | 0.085 | |
| | | | | | | 1.000 | 0.700 | |
| | | | | | | 10.000 | 5.653 | |
| | | | | | | 100.000 | 44.481 | |
| URL5 259.00 | 216. | 55. | 214. | 133. | 6.5 | | | CA,HE |
| | | | | | | 0.001 | 0.002 | |
| | | | | | | 0.010 | 0.014 | |
| | | | | | | 0.100 | 0.108 | |
| | | | | | | 1.000 | 0.859 | |
| | | | | | | 10.000 | 6.787 | |
| | | | | | | 100.000 | 52.419 | |
| URL6 18.39 | 35. | 76. | 246. | 150. | 7.0 | | | CA,HE |
| | | | | | | 0.001 | 0.002 | |
| | | | | | | 0.010 | 0.015 | |
| | | | | | | 0.100 | 0.116 | |
| | | | | | | 1.000 | 0.905 | |
| | | | | | | 10.000 | 7.038 | |
| | | | | | | 100.000 | 53.481 | |

## PEAK SHEAR STRENGTH ESTIMATION

| SAMPLE NUMBER | STRIKE | DIP | UNIAXIAL COMP. STRENGTH (MPa) | JOINT WALL COMP. STRENGTH (MPa) | JRC ESTIMATE | NORMAL STRESS (MPa) | SHEAR STRENGTH (MPa) | INFILLING MATERIAL |
|---|---|---|---|---|---|---|---|---|
| URL6 21.63 | 145. | 47. | 189. | 95. | 3.5 | | | CL,BI |
| | | | | | | 0.001 | 0.001 | |
| | | | | | | 0.010 | 0.008 | |
| | | | | | | 0.100 | 0.072 | |
| | | | | | | 1.000 | 0.629 | |
| | | | | | | 10.000 | 5.468 | |
| | | | | | | 100.000 | 46.995 | |
| URL6 93.06 | N/A | N/A | 214. | 126. | 7.5 | | | HE |
| | | | | | | 0.001 | 0.002 | |
| | | | | | | 0.010 | 0.016 | |
| | | | | | | 0.100 | 0.118 | |
| | | | | | | 1.000 | 0.909 | |
| | | | | | | 10.000 | 6.945 | |
| | | | | | | 100.000 | 51.573 | |
| URL6 117.01 | 63. | 75. | 152. | 60. | 6.5 | | | BI,PY |
| | | | | | | 0.001 | 0.001 | |
| | | | | | | 0.010 | 0.011 | |
| | | | | | | 0.100 | 0.088 | |
| | | | | | | 1.000 | 0.693 | |
| | | | | | | 10.000 | 5.368 | |
| | | | | | | 100.000 | 39.850 | |
| URL6 124.13 | 356. | 65. | 172. | 92. | 4.5 | | | CL,BI |
| | | | | | | 0.001 | 0.001 | |
| | | | | | | 0.010 | 0.009 | |
| | | | | | | 0.100 | 0.081 | |
| | | | | | | 1.000 | 0.685 | |
| | | | | | | 10.000 | 5.749 | |
| | | | | | | 100.000 | 47.475 | |
| URL6 134.62 | 211. | 85. | 220. | 134. | 7.0 | | | CL,HE |
| | | | | | | 0.001 | 0.002 | |
| | | | | | | 0.010 | 0.015 | |
| | | | | | | 0.100 | 0.114 | |
| | | | | | | 1.000 | 0.890 | |
| | | | | | | 10.000 | 6.912 | |
| | | | | | | 100.000 | 52.398 | |
| URL6 145.63 | 78. | 64. | 222. | 192. | 5.0 | | | NO |
| | | | | | | 0.001 | 0.001 | |
| | | | | | | 0.010 | 0.012 | |
| | | | | | | 0.100 | 0.102 | |
| | | | | | | 1.000 | 0.854 | |
| | | | | | | 10.000 | 7.128 | |
| | | | | | | 100.000 | 58.865 | |

## PEAK SHEAR STRENGTH ESTIMATION

| SAMPLE NUMBER | STRIKE | DIP | UNIAXIAL COMP. STRENGTH (MPa) | JOINT WALL COMP. STRENGTH (MPa) | JRC ESTIMATE | NORMAL STRESS (MPa) | SHEAR STRENGTH (MPa) | INFILLING MATERIAL |
|---|---|---|---|---|---|---|---|---|
| URL6 158.90 | 360. | 86. | 158. | 102. | 4.0 | | | CL, CA, HE |
| | | | | | | 0.001 | 0.001 | |
| | | | | | | 0.010 | 0.009 | |
| | | | | | | 0.100 | 0.080 | |
| | | | | | | 1.000 | 0.695 | |
| | | | | | | 10.000 | 5.963 | |
| | | | | | | 100.000 | 50.531 | |
| URL6 161.00 | 360. | 84. | 213. | 179. | 5.0 | | | CA, HE |
| | | | | | | 0.001 | 0.001 | |
| | | | | | | 0.010 | 0.012 | |
| | | | | | | 0.100 | 0.100 | |
| | | | | | | 1.000 | 0.842 | |
| | | | | | | 10.000 | 7.031 | |
| | | | | | | 100.000 | 57.996 | |
| URL6 265.36 | 37. | 31. | 181. | 143. | 4.5 | | | NO |
| | | | | | | 0.001 | 0.001 | |
| | | | | | | 0.010 | 0.011 | |
| | | | | | | 0.100 | 0.092 | |
| | | | | | | 1.000 | 0.784 | |
| | | | | | | 10.000 | 6.643 | |
| | | | | | | 100.000 | 55.652 | |
| URL6 266.18 | 12. | 29. | 132. | 114. | 5.0 | | | HE |
| | | | | | | 0.001 | 0.001 | |
| | | | | | | 0.010 | 0.012 | |
| | | | | | | 0.100 | 0.097 | |
| | | | | | | 1.000 | 0.813 | |
| | | | | | | 10.000 | 6.775 | |
| | | | | | | 100.000 | 55.702 | |
| URL7 22.16 | 270. | 78. | 186. | 102. | 7.5 | | | CA, HE |
| | | | | | | 0.001 | 0.002 | |
| | | | | | | 0.010 | 0.015 | |
| | | | | | | 0.100 | 0.113 | |
| | | | | | | 1.000 | 0.866 | |
| | | | | | | 10.000 | 6.590 | |
| | | | | | | 100.000 | 48.525 | |
| URL7 63.27 | 234. | 58. | 219. | 87. | 13.0 | | | NO |
| | | | | | | 0.001 | 0.032 | |
| | | | | | | 0.010 | 0.038 | |
| | | | | | | 0.100 | 0.190 | |
| | | | | | | 1.000 | 1.159 | |
| | | | | | | 10.000 | 7.321 | |
| | | | | | | 100.000 | 42.872 | |

PEAK SHEAR STRENGTH ESTIMATION

| SAMPLE NUMBER | STRIKE | DIP | UNIAXIAL COMP. STRENGTH (MPa) | JOINT WALL COMP. STRENGTH (MPa) | JRC ESTIMATE | NORMAL STRESS (MPa) | SHEAR STRENGTH (MPa) | INFILLING MATERIAL |
|---|---|---|---|---|---|---|---|---|
| URL7 68.72 | 165. | 82. | 170. | 105. | 6.0 | | | CA,HE |
| | | | | | | 0.001 | 0.002 | |
| | | | | | | 0.010 | 0.012 | |
| | | | | | | 0.100 | 0.099 | |
| | | | | | | 1.000 | 0.801 | |
| | | | | | | 10.000 | 6.418 | |
| | | | | | | 100.000 | 50.279 | |
| URL7 84.88 | 31. | 90. | 150. | 121. | 6.0 | | | CA,HE |
| | | | | | | 0.001 | 0.002 | |
| | | | | | | 0.010 | 0.013 | |
| | | | | | | 0.100 | 0.107 | |
| | | | | | | 1.000 | 0.866 | |
| | | | | | | 10.000 | 6.975 | |
| | | | | | | 100.000 | 55.191 | |
| URL7 155.42 | 67. | 70. | 173. | 115. | 9.0 | | | CA,HE |
| | | | | | | 0.001 | 0.003 | |
| | | | | | | 0.010 | 0.020 | |
| | | | | | | 0.100 | 0.141 | |
| | | | | | | 1.000 | 1.023 | |
| | | | | | | 10.000 | 7.440 | |
| | | | | | | 100.000 | 52.384 | |
| URL7 164.60 | 122. | 32. | 194. | 107. | 7.5 | | | CL,HE |
| | | | | | | 0.001 | 0.002 | |
| | | | | | | 0.010 | 0.015 | |
| | | | | | | 0.100 | 0.114 | |
| | | | | | | 1.000 | 0.875 | |
| | | | | | | 10.000 | 6.664 | |
| | | | | | | 100.000 | 49.162 | |
| URL7 173.17 | 119. | 18. | 165. | 80. | 5.0 | | | NO |
| | | | | | | 0.001 | 0.001 | |
| | | | | | | 0.010 | 0.010 | |
| | | | | | | 0.100 | 0.082 | |
| | | | | | | 1.000 | 0.684 | |
| | | | | | | 10.000 | 5.625 | |
| | | | | | | 100.000 | 45.274 | |

Table 4 - Effect of varying JRC on the peak shear strength estimate (MPa)

| Normal stress | JRC | | |
|---|---|---|---|
| (MPa) | 4.5 | 5.5 | 6.5 |
| 0.001 | 0.001 | 0.001 | 0.002 |
| 0.010 | 0.010 | 0.011 | 0.013 |
| 0.100 | 0.083 | 0.092 | 0.103 |
| 1.000 | 0.704 | 0.759 | 0.818 |
| 10.000 | 5.923 | 6.177 | 6.437 |
| 100.000 | 49.068 | 49.214 | 49.360 |

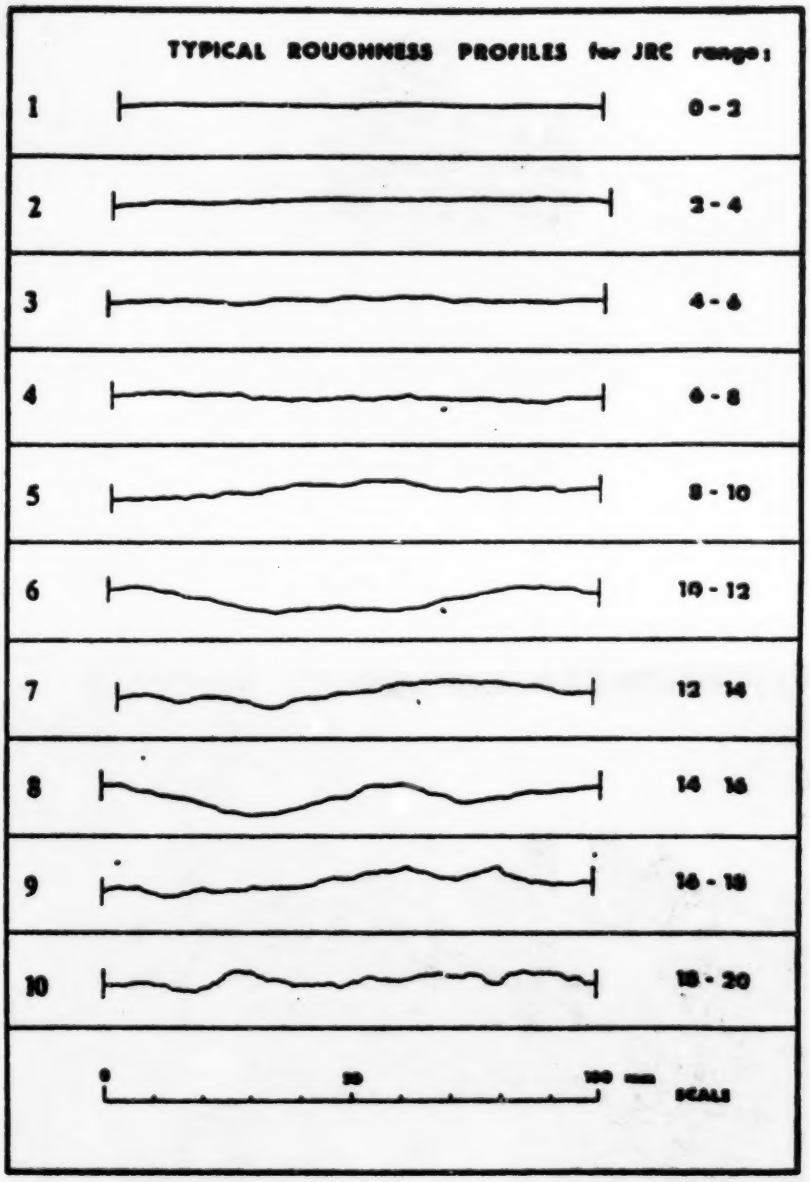


Fig. 1 - Typical roughness profiles. (After Barton et al).

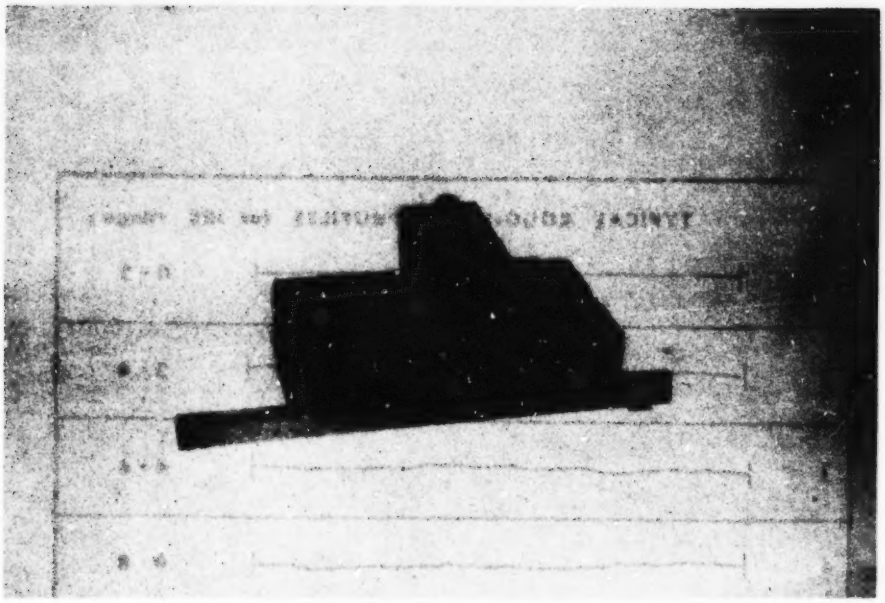

Fig. 2 - Schmidt hammer test base

Fig. 3 - Basic friction angle tilt table

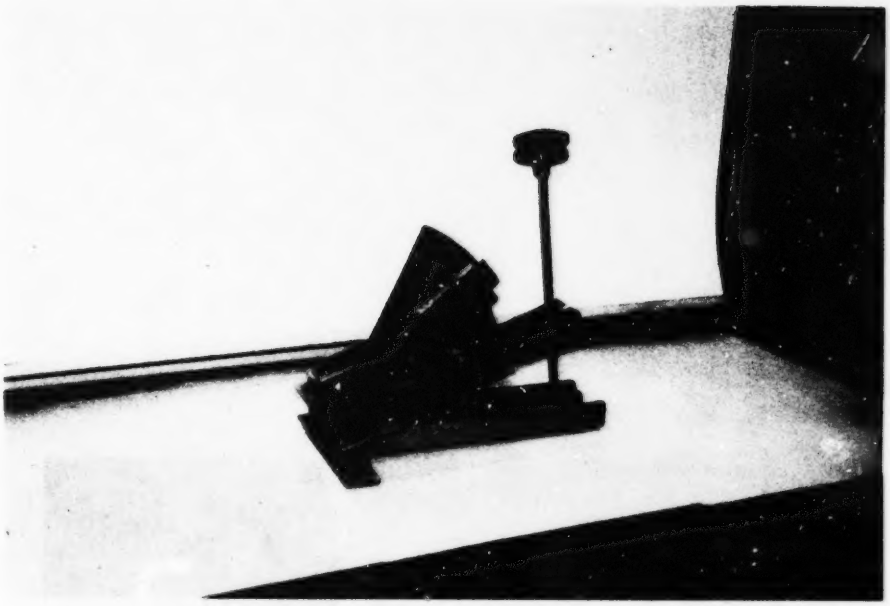

Fig. 4 - Small scale tilt table

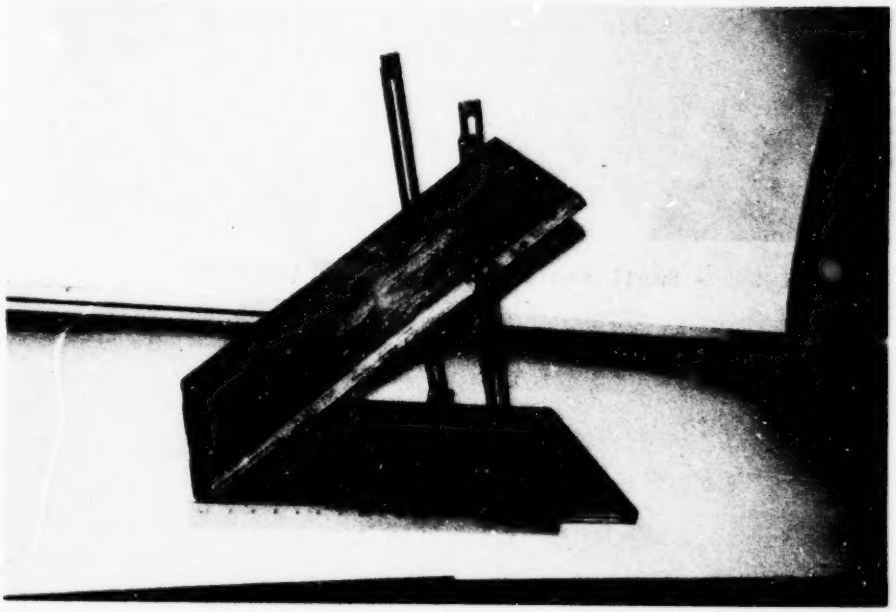

Fig. 5 - Large scale tilt table

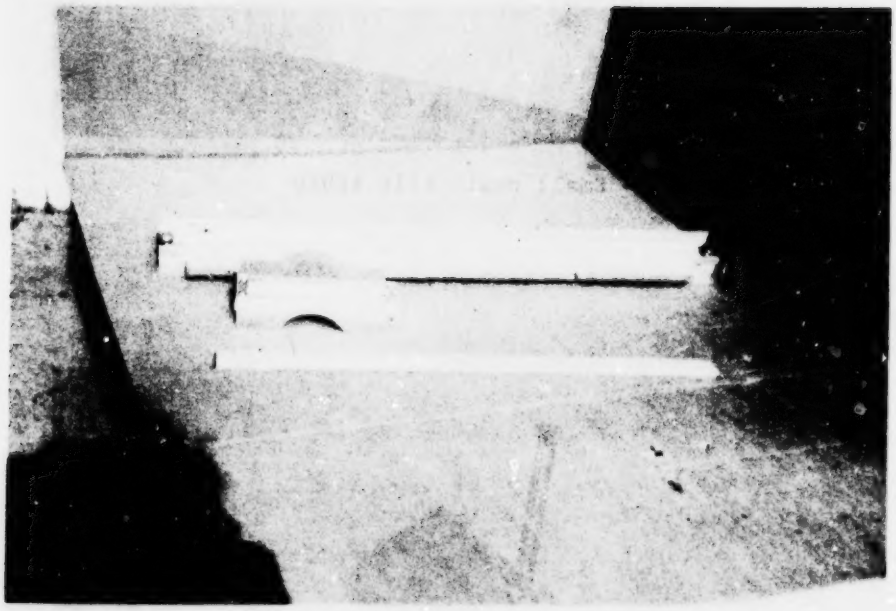

Fig. 6 - Small and large scale profilometers